the binarization image to form real vessel regions from the vessel candidates. In one embodiment, the vessel classification may include a size test, which evaluates the goodness of fit to a cylindrical tube, for filtering out tiny background clutters, a structure-based vessel test for removing non-vessel type clutters, i.e., an initial vessel test, a gradient magnitude analysis, and a final vessel test for precisely removing the clutters. Although some clutters are not removed through the structure-based vessel test, an initial threshold may be marginally set so that all vessels may be included. For example, a threshold value of the initial vessel test may be set to 0.6. At the final vessel test, clutters, which may be formed by small shading artifacts having low gradient magnitudes, may be precisely removed by considering variation of voxel values, i.e., gradient magnitudes, to thereby extract vessel data. In one embodiment, a threshold of the final vessel test may be set to 0.4.

[0041] The diaphragm refining section **143** may be configured to refine the diaphragm region by removing the clutters with the extracted vessel regions. The clutters are mainly placed near the vessel walls. Especially, the vessel walls of inferior vena cava (IVC) are more likely to be connected to the diaphragm and cause clutters. These clutters may degrade the accuracy of the feature based registration, and thus, it may be necessary to refine the diaphragm region. To refine the diaphragm, the vessel regions are extracted according to the vessel extraction mentioned above, the extracted vessel regions may be dilated, and then the dilated vessel regions may be subtracted from the initially extracted diaphragm region to estimate vessel walls. The estimated vessel walls may be removed from the diaphragm region. Finally, the diaphragm region may be extracted by applying CCA and the size test.

[0042] The registration section **144** may be configured to perform the image registration between the three-dimensional ultrasound and CT image. The registration section **144** may extract sample points from the vessel regions and the diaphragm region, respectively, among the features extracted from the three-dimensional ultrasound image. Also, after the vessel regions and the diaphragm region are extracted from the CT image, the registration section **144** may extract sample points from the vessel and the diaphragm region, respectively. The image registration between the three-dimensional ultrasound and CT image may be performed based on the extracted sample points to thereby form the transformation function (T_{probe}) between the three-dimensional CT image and the three-dimensional ultrasound image. The transformation function (T_{probe}) may be given by a matrix and used to transform a position of the ultrasound probe **112** to a corresponding position on the three-dimensional CT image.

[0043] The calibration section **145** may perform the calibration of the sensor **120** based on the transformation matrix (T_{probe}) from the registration section **144** and the position information stored in the memory **130**. More particularly, the calibration section **145** may form a transformation matrix (T_{sensor}) between the sensor **120** and the three-dimensional ultrasound image, i.e., a transformation matrix representing a position of the sensor **120** with respect to the three-dimensional ultrasound image. The transformation matrix (T_{sensor}) may be given by a matrix. The transformation matrix (T_{sensor}) may be defined as the following equation (3).

$$I_{sensor} = \begin{vmatrix} r11 & r12 & r13 & x \\ r21 & r22 & r23 & y \\ r31 & r32 & r33 & z \\ 0 & 0 & 0 & 1 \end{vmatrix} \quad (3)$$

$r11=\cos\theta y^*\cos\theta z+\sin\theta x^*\sin\theta y^*\sin\theta z$

$r12=\sin\theta z^*\cos\theta y-\sin\theta x^*\sin\theta y^*\cos\theta z$

$r13=\cos\theta x^*\sin\theta y$, $r21=\sin\theta z^*\cos\theta x$

$r22=\cos\theta z^*\sin\theta x$, $r23=\sin\theta x$

$r31=\sin\theta z^*\sin\theta x^*\cos\theta y-\cos\theta z^*\sin\theta y$

$r32=-\cos\theta z^*\sin\theta x^*\cos\theta y-\sin\theta z^*\sin\theta y$

$r33=\cos\theta x^*\cos\theta y$

wherein, x denotes coordinate of a lateral direction of the sensor **120**, y denotes coordinate of an elevation direction of the sensor **120**, z denotes an axial direction of the sensor **120**, θ_x denotes an angle of the sensor **120** from the x-axis, θ_y denotes an angle of the sensor **120** from the y-axis, and θ_z denotes an angle of the sensor **120** from the z-axis. The elevation direction may be a swing direction of the transducer elements, the axial direction may be a scan line direction from the transducer elements and the lateral direction may be a longitudinal direction of the transducer elements.

[0044] The calibration section **145** may perform the calibration based on the transformation matrix (T_{probe}) and the transformation matrix (T_{sensor}). The calibration section **145** may form a transformation matrix (T) representing the position of the sensor **120** on the three-dimensional CT image. In one embodiment, the calibration section **145** may form the transformation matrix (T) through matrix multiplication of the transformation matrix (T_{probe}) and the transformation matrix (T_{sensor}).

[0045] The image processing section **146** may apply the transformation matrix (T) to the three-dimensional CT image to thereby form a two-dimensional CT image according to a two-dimensional ultrasound image.

[0046] Referring back to FIG. **1**, the display unit **150** may display the two-dimensional CT image, which is provided from the processor **140**. Furthermore, the display unit **150** may display the three-dimensional ultrasound image and the three-dimensional CT image.

[0047] Although the exemplary embodiments above described in detail a CT image as an image to be aligned with the ultrasound image, this is not limiting. For example, the image to be aligned with the ultrasound image may be obtained by various modalities and may be, for example, an optical coherence tomography (OCT) image, a magnetic resonance (MR) image, a single-photon emission computed tomography (SPECT) image, a PET image, a PET-CT image, a PET-MR image, a fluoroscopic image, an X-ray image including an image obtained by a stationary X-ray, a mobile X-ray, a C-arm X-ray, etc., and an image of any other appropriate imaging modality.

[0048] The above-discussed images may be aligned and/or fused in various ways. Further, any two images or an ultrasound image and the fused image may be displayed side by side, partially overlapping, etc.